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* LUNAR ROVING VEHICLE
OPERATIONS HANDBOOK
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APPROVED: Albert Z. Field
LUNAR ROVING VEHICLE
SYSTEMS ENGINEERING MANAGER



PREPARED BY THE BOEING COMPANY
LRV SYSTEMS ENGINEERING
HUNTSVILLE, ALABAMA

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HANDBOOK CONFIGURATION

This handbook reflects the Lunar Roving Vehicle (LRV) and Space Support Equipment (SSE) delivery review configuration as modified by incorporation of the following:

<u>ECP</u>	<u>DESCRIPTION</u>
LRV 1097	Incorporation of Manual SSE
LRV 1073	Seat Belt Modification
LRV 1075	Rear Steering Recoupling
LRV 1104	Thermal Blanket
LRV 1103	Switch Guards

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LRV FLIGHT UNIT PARTIAL DRAWING LIST
(FOR REFERENCE ONLY)

<u>DESCRIPTION</u>	<u>DRAWING NUMBER</u>
Flight Vehicle Assembly	209-35006
Chassis Assembly	209-30006
Tripod	209-30406
Fender	209-31625
Crew Station Installation	209-31006
Suspension and Wheel Installation	209-35206
Steering Installation	209-35306
Electrical and Battery Installation	209-34006
Electrical Cabling Installation	209-35106
Display and Control Console Assembly	209-22200
Gyro and SPU Installation	209-34306
Vehicle Attitude Indicator Installation	209-60050
Thermal Insulation Installation	209-34406
Gyro Thermal Strap	209-70019
SPU Thermal Control Unit	209-70400
DCE Assembly	7553139*
Hand Controller Assembly	7553447*
Traction Drive Assembly	7553102*

*Denotes AC/Delco Electronics Drawings, All Others are Boeing

SECTION I

GENERAL INFORMATION

1.0 INTRODUCTION

This section contains general information pertaining to the flight operational Lunar Roving Vehicle (LRV). Where applicable, the 1G Trainer differences are noted.

1.1 DESCRIPTION

The LRV system on the lunar surface consists of the LRV, the structure for securing the LRV to the LM stowage bay and the mechanism for deploying the LRV from the LM onto the lunar surface.

1.2 VEHICLE SYSTEMS

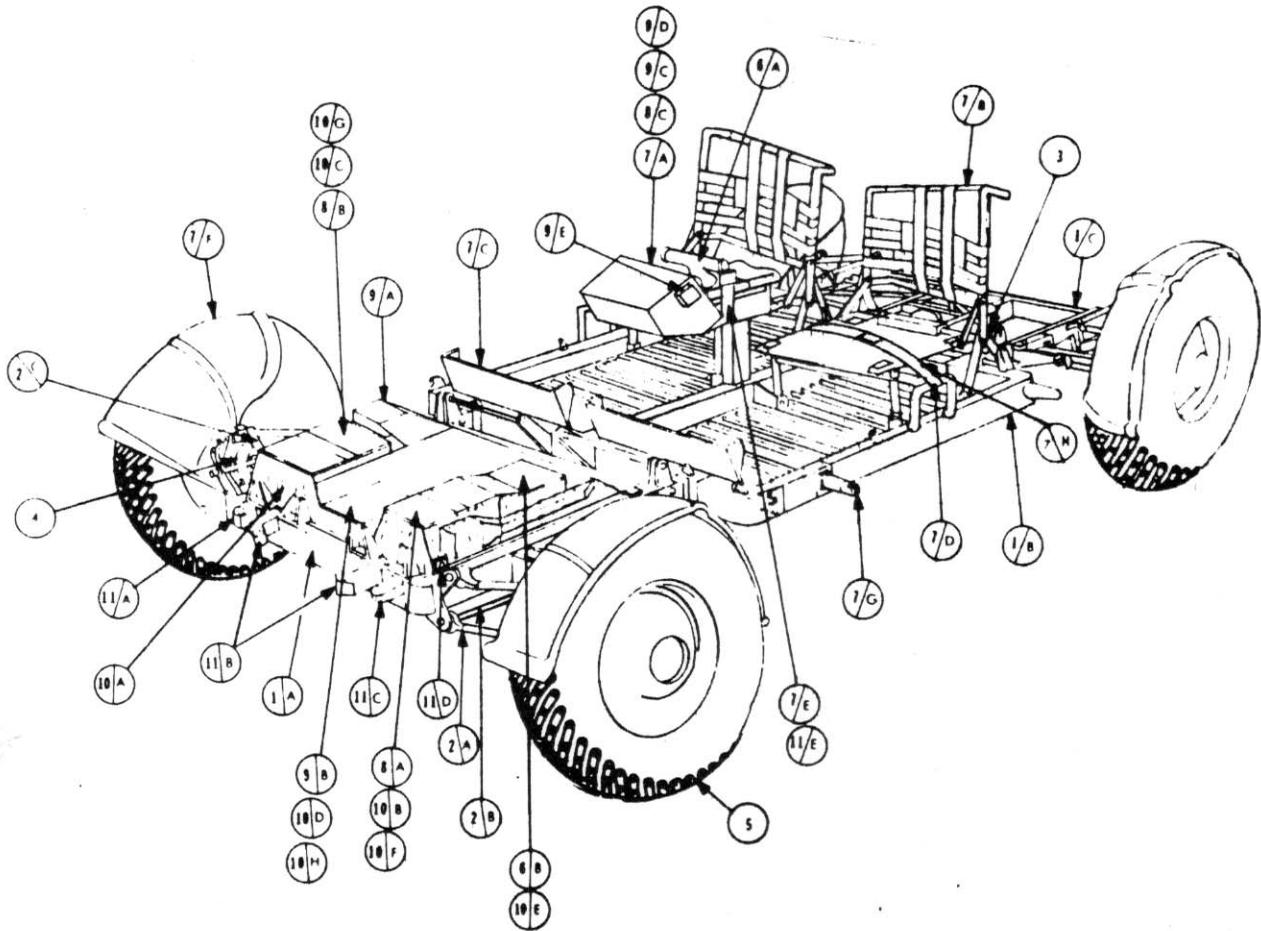
The LRV (figure 1-1) is a four-wheeled, self-propelled, manually controlled vehicle to be used for transporting crewmen and equipment on the lunar surface. The vehicle has accommodations for two crewmen and the stowed auxiliary equipment designed for the particular mission.

Control of the LRV during traverses is effected from either of the two crewmen positions by operating the hand controller located between the two crewmen positions. Selection of power supplied to each load, monitoring of key parameters, and operation of the navigation system is effected from the control and display console, which is located for operation by either crewman.

1G Trainer Notes

1. 1G Trainer vehicle systems are shown on figure 1-2.
2. Electrical block diagrams for the 1G Trainer are provided in Section 8.0.

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- | | | |
|---|---|--|
| <p>① <u>CHASSIS</u></p> <p>A. FORWARD CHASSIS
B. CENTER CHASSIS
C. AFT CHASSIS</p> <p>② <u>SUSPENSION SYSTEM</u></p> <p>A. SUSPENSION ARMS (UPPER AND LOWER)
B. TORSION BARS (UPPER AND LOWER)
C. DAMPLER</p> <p>③ <u>STEERING SYSTEM (FORWARD AND AFT)</u></p> <p>④ <u>TRACTION DRIVE</u></p> <p>⑤ <u>WHEEL</u></p> <p>⑥ <u>DRIVE CONTROL</u></p> <p>A. HAND CONTROLLER
B. DRIVE CONTROL ELECTRONICS (DCE)</p> | <p>⑦ <u>CREW STATION</u></p> <p>A. CONTROL AND DISPLAY CONSOLE
B. SEAT
C. FOOTREST
D. OUTBOARD HANDHOLD
E. INBOARD HANDHOLD
F. FENDER
G. TOEHOLD
H. SEAT BELT</p> <p>⑧ <u>POWER SYSTEM</u></p> <p>A. BATTERY #1
B. BATTERY #2
C. INSTRUMENTATION</p> <p>⑨ <u>NAVIGATION</u></p> <p>A. DIRECTIONAL GYRO UNIT (DGU)
B. SIGNAL PROCESSING UNIT (SPU)
C. INTEGRATED POSITION INDICATOR (IPI)
D. SUN SHADOW DEVICE
E. VEHICLE ATTITUDE INDICATOR</p> | <p>⑩ <u>THERMAL CONTROL</u></p> <p>A. INSULATION BLANKET
B. BATTERY NO. 1 DUST COVER
C. BATTERY NO. 2 DUST COVER
D. SPW DUST COVER
E. DEL THERMAL CONTROL UNIT
F. BATTERY NO. 1 RADIATOR
G. BATTERY NO. 2 RADIATOR
H. SPW THERMAL CONTROL UNIT</p> <p>⑪ <u>PAYLOAD INTERFACE</u></p> <p>A. TV CAMERA RECEPTACLE
B. LCRU RECEPTACLE
C. HIGH GAIN ANTENNA RECEPTACLE
D. AUXILIARY CONNECTOR
E. LOW GAIN ANTENNA RECEPTACLE</p> |
|---|---|--|

FIGURE 1-1 LRV WITHOUT STOWED PAYLOAD (SHEET 1 OF 2)

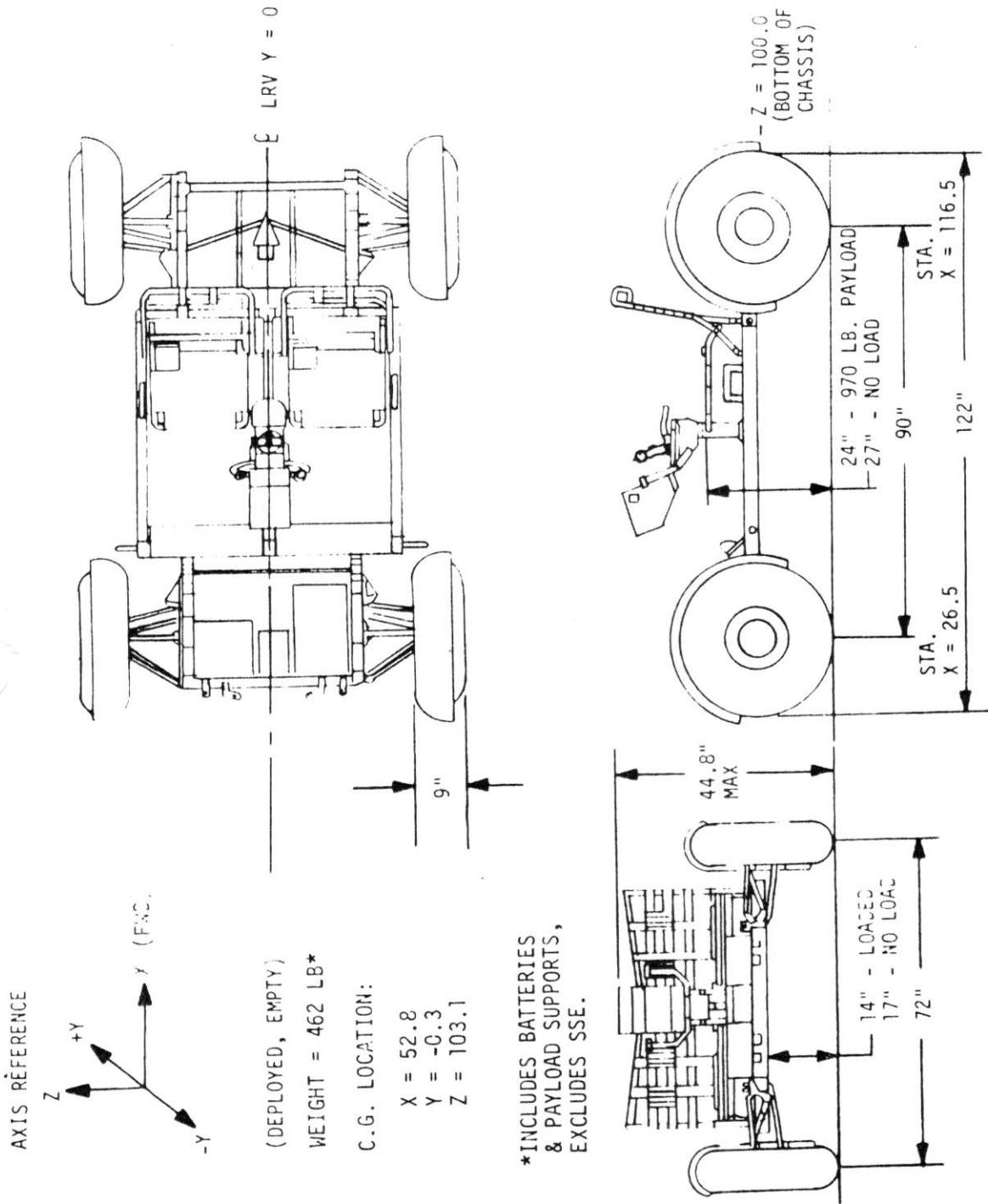


FIGURE 1-1 LRV COMPONENTS AND DIMENSIONS (SHEET 2 OF 2)

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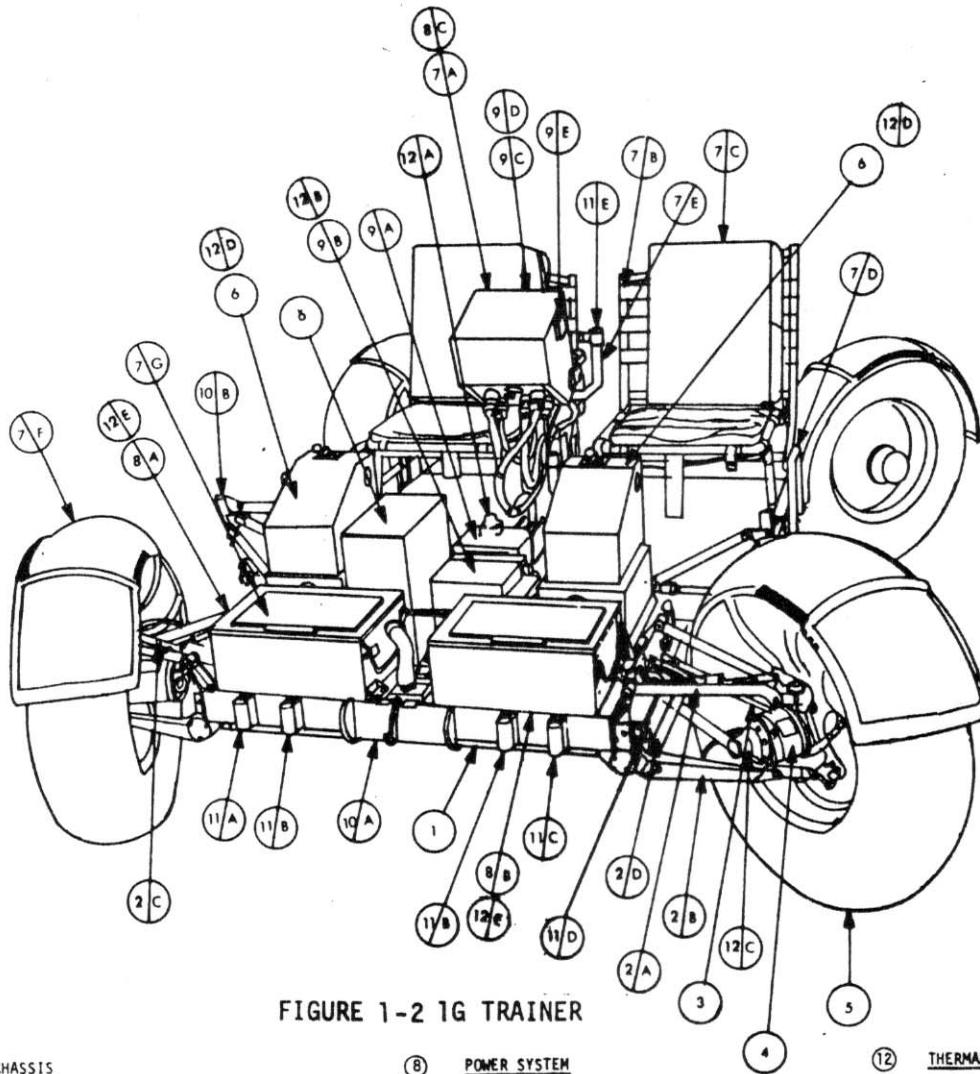


FIGURE 1-2 1G TRAINER

- | | | |
|--|--|---|
| <p>① <u>CHASSIS</u></p> <p>② <u>SUSPENSION SYSTEM</u></p> <p>A. UPPER ARM
B. LOWER ARM
C. DAMPER
D. TORSION BAR</p> <p>③ <u>STEERING SYSTEM (FORWARD AND REAR)</u></p> <p>④ <u>TRACTION DRIVE</u></p> <p>⑤ <u>WHEEL</u></p> <p>⑥ <u>DRIVE CONTROLLERS</u></p> <p>⑦ <u>CREW STATION</u></p> <p>A. CONTROL AND DISPLAY CONSOLE
B. SLAT
C. REMOVABLE PAD (FOR UNSUITED CREW USE)
D. OUTBOARD HANDHOLD
E. INBOARD HANDHOLD
F. FENDER
G. SIMULATED DUST COVER</p> | <p>⑧ <u>POWER SYSTEM</u></p> <p>A. BATTERY #1
B. BATTERY #2
C. INSTRUMENTATION</p> <p>⑨ <u>NAVIGATION</u></p> <p>A. DIRECTIONAL GYRO UNIT (DGU)
B. SIGNAL PROCESSING UNIT (SPU)
C. INTEGRATED POSITION INDICATOR (IPI)
D. SUN SHADOW DEVICE
E. ATTITUDE INDICATOR</p> <p>⑩ <u>DEPLOYMENT SIMULATION</u></p> <p>A. FORWARD CHASSIS SADDLE SIMULATOR
B. TRIPOD SIMULATORS (BOTH SIDES)</p> <p>⑪ <u>PAYLOAD INTERFACE</u></p> <p>A. TV CAMERA RECEPTACLE
B. LCRU RECEPTACLE
C. HIGH GAIN ANTENNA RECEPTACLE
D. AUXILIARY CONNECTOR
E. LOW GAIN ANTENNA RECEPTACLE</p> | <p>⑫ <u>THERMAL CONTROL</u></p> <p>A. DGU HEAT EXCHANGER
B. SPU HEAT EXCHANGER
C. TRACTION DRIVE BLOWERS (4)
D. DCE BLOWERS
E. BATTERY BLOWER</p> |
|--|--|---|

1.3 MOBILITY SUBSYSTEM

The mobility subsystem (figure 1-3) consists of the chassis and equipment and controls necessary to propel, suspend, brake and steer the LRV.

1.3.1 Wheel

Each wheel (figure 1-4, Sh 1) includes an open wire mesh tire with chevron tread covering 50 percent of the surface contact area. The tire inner frame prevents excessive deflection of the outer wire mesh frame under high impact load conditions.

Each wheel has a decoupling mechanism (figure 1-5) and can be decoupled from the traction drive by operating the two decoupling mechanisms (figure 1-10) which allows the wheel to "free-wheel" about a bearing independent of the drive train. This decoupling mechanism can also be used to re-engage the wheel with the traction drive. Decoupling disables the brake on the affected wheel.

1G Trainer Notes

1. The 1G Trainer tires for primary use are pneumatic automobile tires (figure 1-4, Sh 2) Special wire mesh wheels are also available for use with the 1G Trainer.
2. The 1G Trainer has simulated wheel decoupling mechanisms to duplicate the LRV-to-Crew interface. Operation of this simulated mechanism, however, will not effect actual decoupling. Procedures for 1G Trainer wheel decoupling are shown in Section 8. Wheel decoupling on the 1G Trainer does not disable the brake on the affected wheels.

1.3.2 Traction Drive

Each wheel is provided with a separate traction drive (figure 1-5, Sh 1) consisting of a harmonic drive reduction unit, drive motor and brake assembly. Each traction drive is hermetically sealed to maintain a 7.5 PSIA internal pressure for improved brush lubrication. Each traction drive also contains an odometer pickup which transmits a pulse to the navigation system signal processing unit at the rate of nine pulses per wheel revolution.

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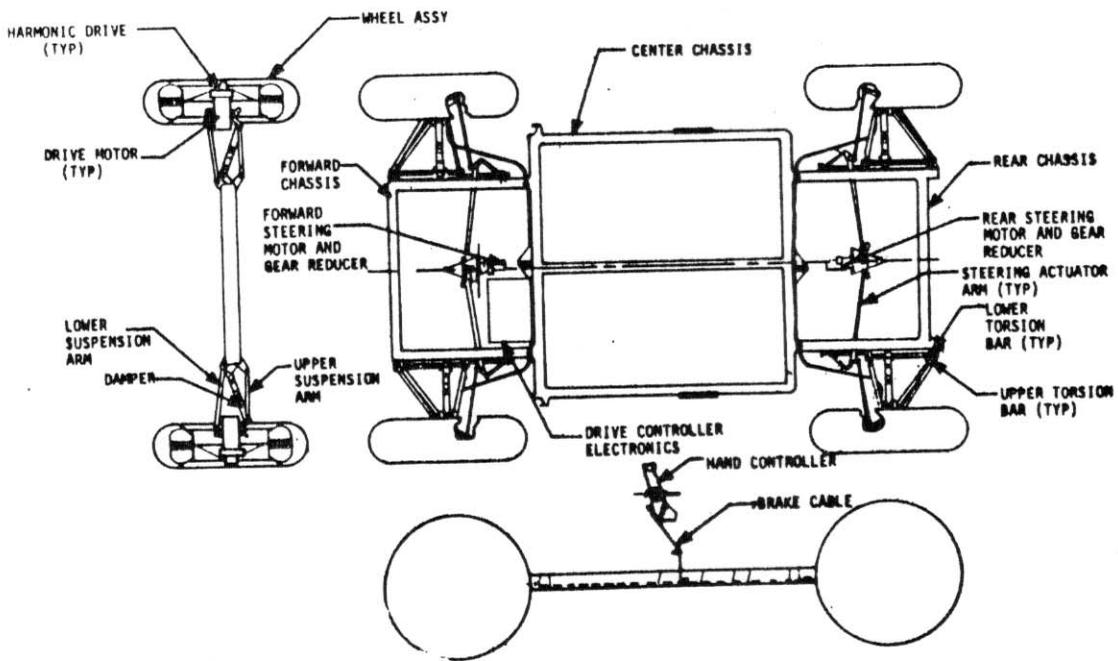


FIGURE 1-3 MOBILITY SUBSYSTEM

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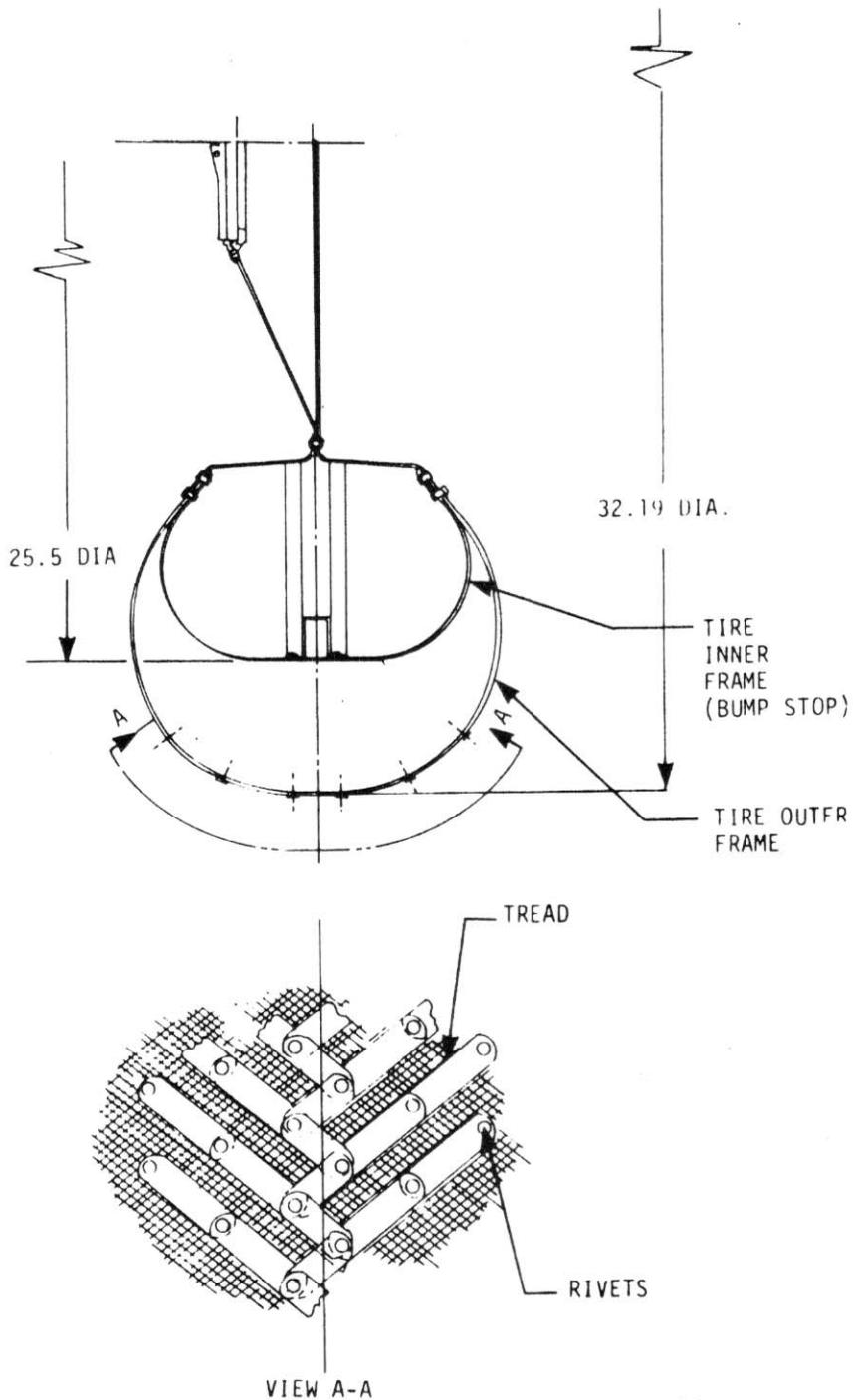


FIGURE 1-4 LRV WHEEL CROSS-SECTION (SHEET 1 OF 2)

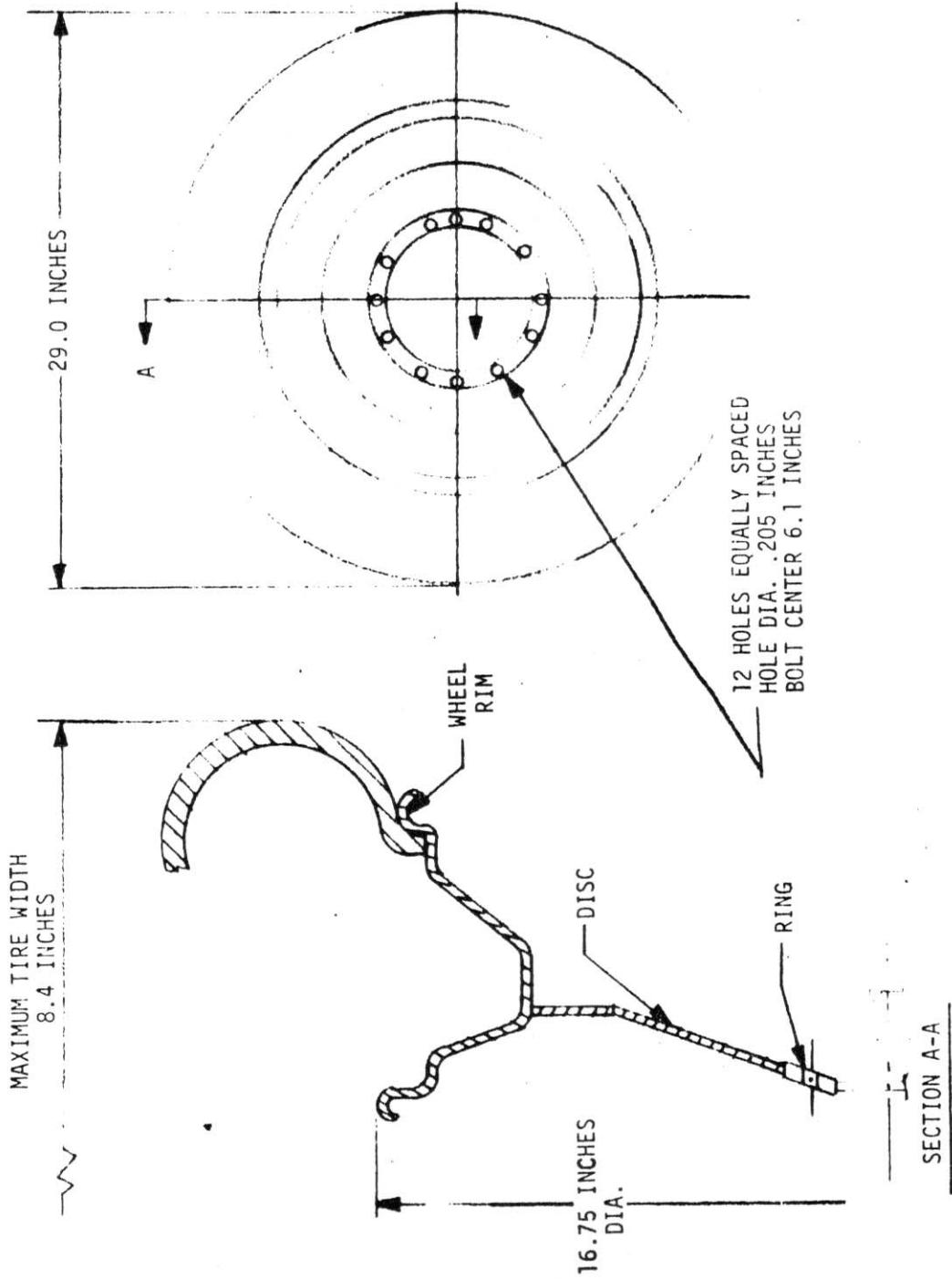


FIGURE 1-4 16 TRAINER WHEEL AND PNEUMATIC TIRE (SHEET 2 OF 2)

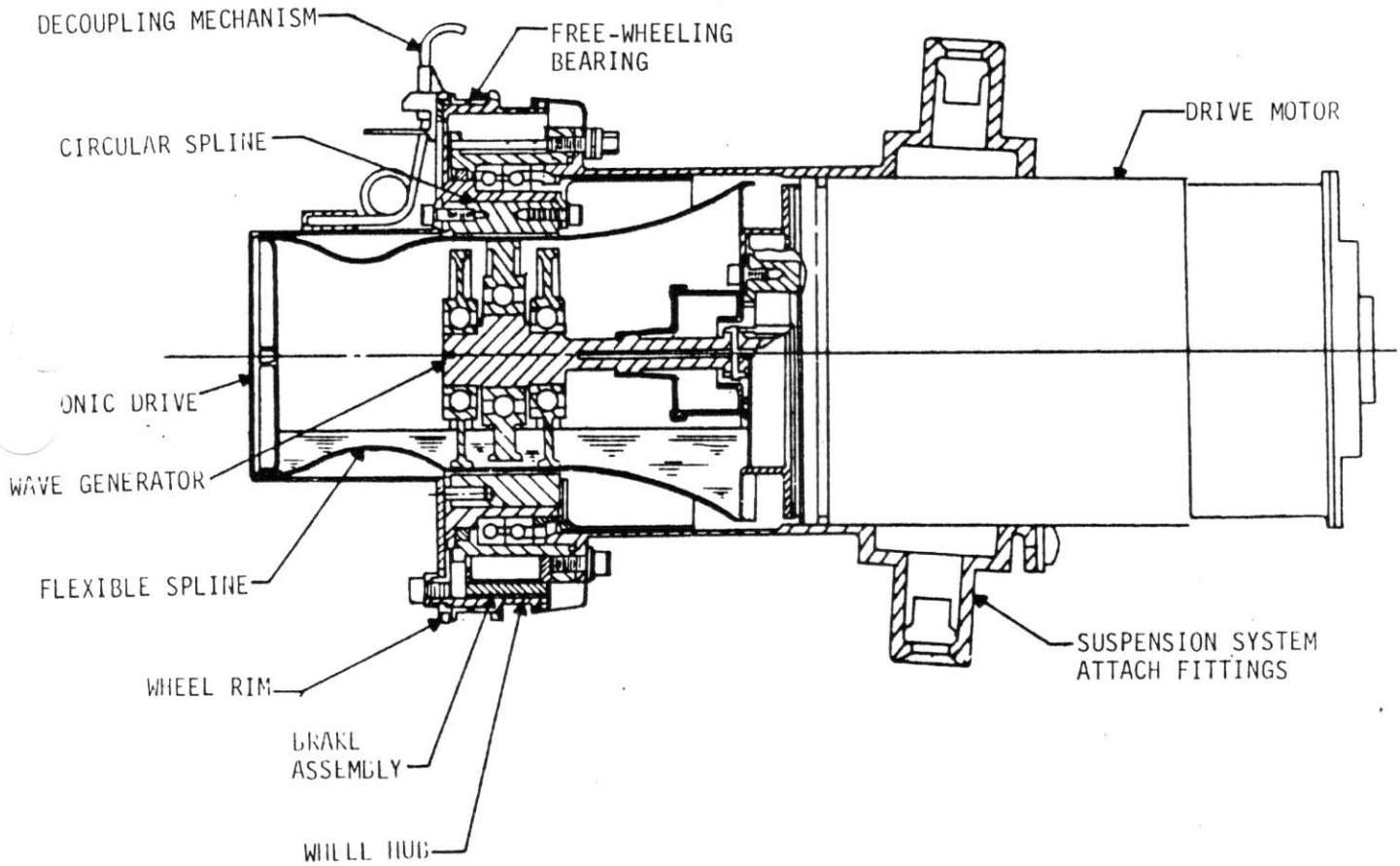


FIGURE 1-5. LRV TRACTION DRIVE ASSEMBLY (SHEET 1 OF 2)

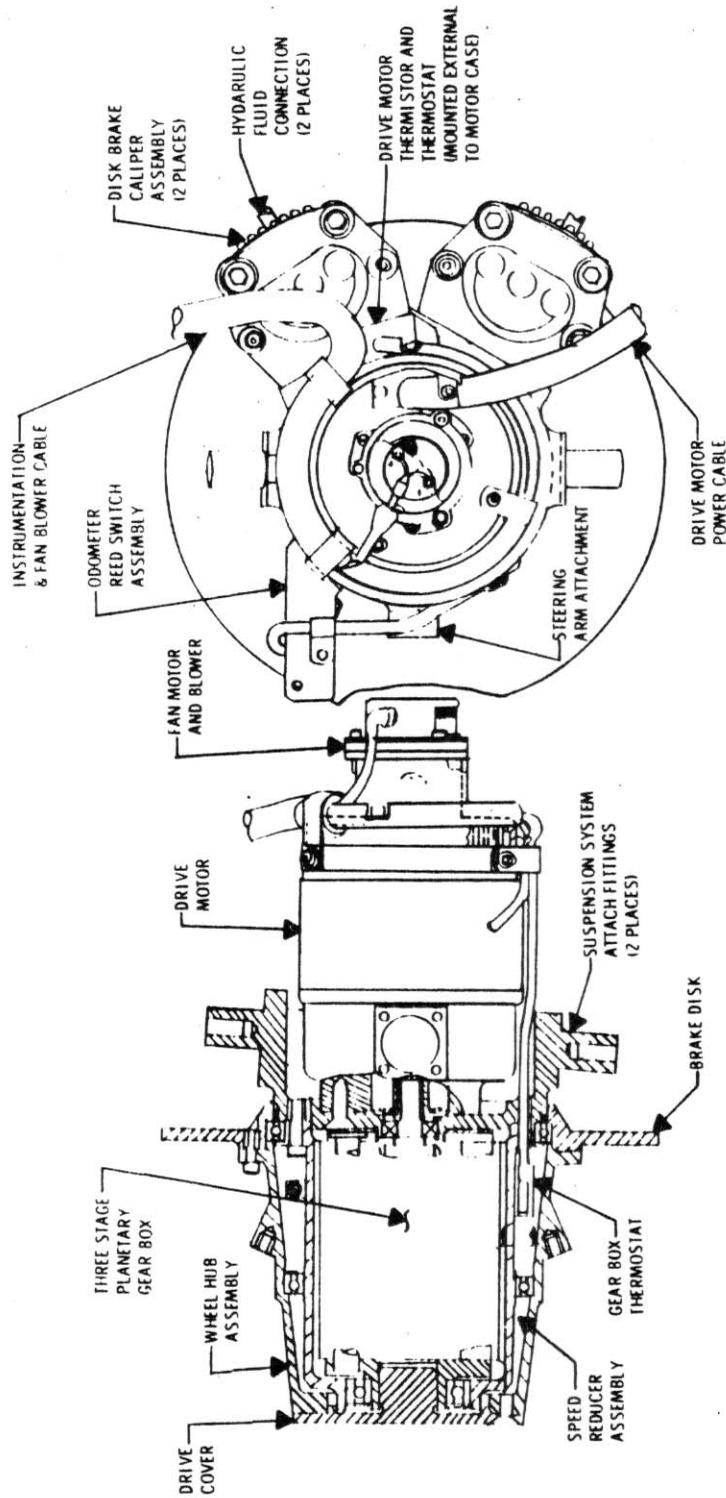


FIGURE 1-5 1G TRAINER TRACTION DRIVE ASSEMBLY (SHEET 2 OF 2)

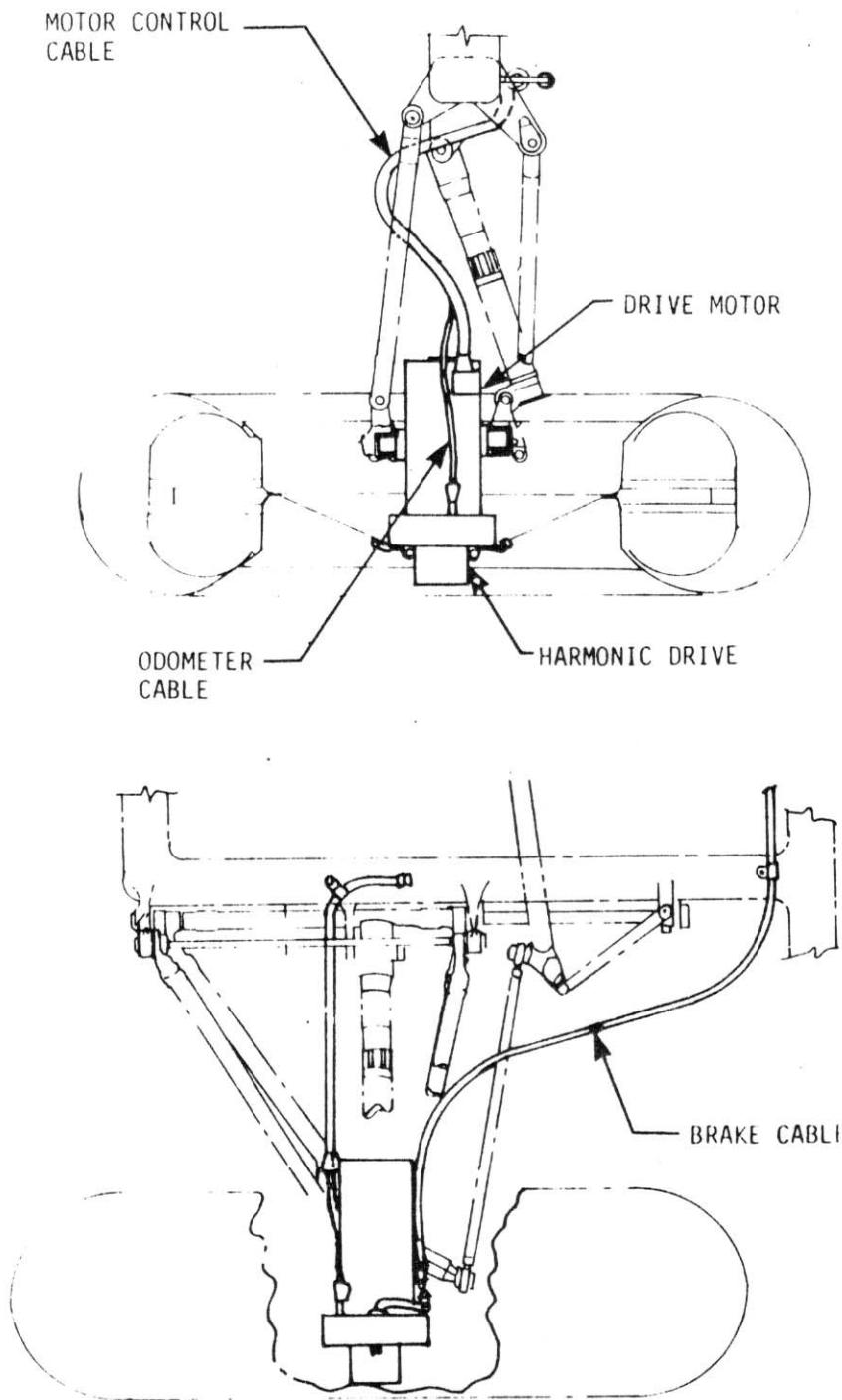


FIGURE 1-6. TRACTION DRIVE INSTALLATION

1G Trainer Notes

1. The traction drive for the 1G Trainer has a 3-stage planetary gear box in lieu of the harmonic drive, (figure 1-5, Sh 2).
2. 1G Trainer traction drives are not hermetically sealed.

1.3.2.1 Harmonic Drive

The four harmonic drive reduction units transmit torque to each wheel. Input torque to the four harmonic drives is supplied by the four electric drive motors. The harmonic drives reduce the motor speed at the rate of 80:1 and allow continuous application of torque to the wheels at all speeds without requiring gear shifting. Speed/torque/efficiency characteristics of the harmonic drive units are shown in Appendix A.

1.3.2.2 Drive Motor

The drive motors are direct current series, brush type motors which operate from a nominal input voltage of 36 VDC. Speed control for the motors is furnished by pulse width modulation from the drive controller electronic package. Performance characteristics for the drive motors are shown in Appendix A. Suspension system attach fittings on each motor also form the king-pin for the LRV steering system. Each motor is instrumented for thermal monitoring. An analog temperature measurement from a thermistor at the stator field is displayed on the control and display panel. In addition, each motor contains a thermal switch which closes on increasing temperature at 400°F and provides an input signal to the caution and warning system to actuate the warning flag.

1G Trainer Notes

1. The 1G Trainer drive motors operate from a nominal input voltage of 34 VDC.
2. The 1G Trainer gear box thermal switch will actuate the warning flag when a gear box temperature reaches 200°F. The indicated temperature, however, will be 450°F to 500°F upon actuation, since the readouts are biased.
3. The 1G Trainer motor temperature switch is set to actuate the flag when the motor external case temperature reaches 225°F. This temperature at the case would correspond to a rotor temperature of about 450°F.

1.3.2.3 Brakes

Each traction drive is equipped with a mechanical brake actuated by a cable connected to a linkage in the hand controller. Stopping distance capability using these brakes is shown in Appendix A.

Braking is accomplished by moving the hand controller rearward. This operation de-energizes the drive motor and, through a linkage and cable, forces brake shoes against a brake drum which stops the rotation of the wheel hub about the harmonic drive.

1G Trainer Note

The 1G Trainer brakes are hydraulically actuated disc brakes. Brakes are actuated by the hand controller in the same manner as the LRV mechanical brakes.

1.3.3 Suspension

The chassis (figure 1-7) is suspended from each wheel by a pair of parallel triangular arms connected between the LRV chassis and each traction drive. Loads are transmitted to the chassis through each suspension arm to a separate torsion bar for each arm. Wheel vertical travel and rate of travel is limited by a linear damper connected between the chassis and each traction drive. The deflection of the suspension system and tires combine to allow 14 inches of chassis ground clearance when the LRV is fully loaded and 17 inches when unloaded.

Damping energy heats the fluid in the damper. The heat is conducted from the fluid to the damper walls for dissipation.

The suspension systems can be rotated approximately 135 degrees to allow folding and LRV stowage in the LM.

1G Trainer Notes

1. 1G Trainer suspension is not designed to allow folding for LM stowage.
2. 1G Trainer suspension system contains only a lower torsion bar on each wheel.

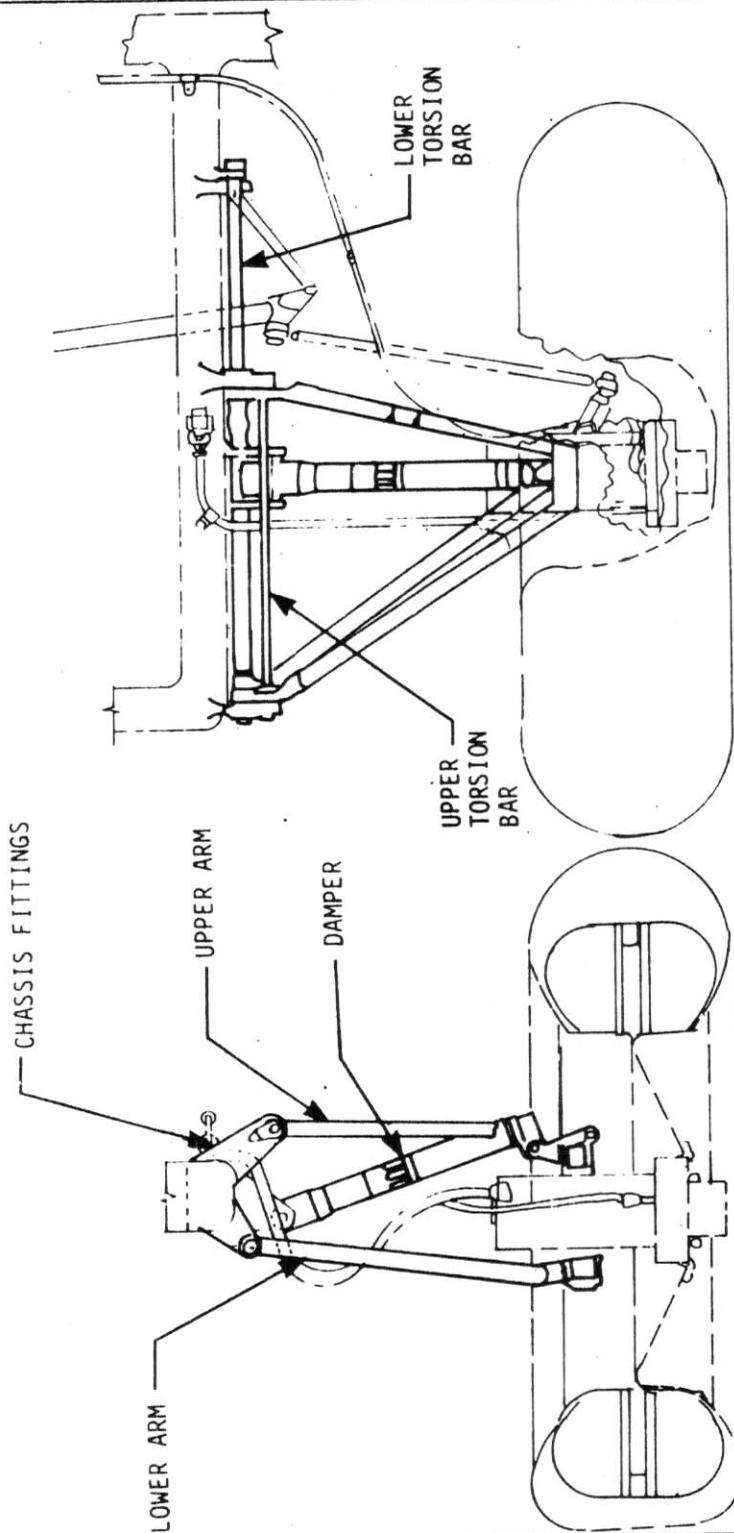


FIGURE 1-7. SUSPENSION ASSEMBLY

1.3.4 Steering

LRV steering (figure 1-8) is accomplished by Ackermann-geometry steering of both the front and rear wheels allowing a wall-to-wall turning radius of 122 inches. Steering is controlled by moving the hand controller left or right from the nominal position. This operation energizes separate electric motors for the front and rear wheels, and through a servo system, provides a steering angle proportional to the position of the hand controller. (The steering control block diagram is shown in figure 1-9).

Each steering motor is connected to a speed reducer which drives a spur gear sector which, in turn, actuates the steering linkage to accomplish the change in steering angle. Maximum travel position of the sector provides an outer wheel angle of 22 degrees and inner wheel angle of 50 degrees. The steering rate is such that lock-to-lock steering can be accomplished in 5.5 (+ 0.5) seconds.

The front and rear steering assemblies are mechanically independent of each other. In the event of motor/speed reducer failure, the steering linkage can be disengaged from the sector, the wheels can be centered and locked, and operations can continue using the remaining active steering assembly. Steering disconnect points are shown in figure 1-10. Forward steering reconnection cannot be accomplished by a crewman. The rear steering reconnection can be accomplished by a crewman as described in Section 2.9.

1G Trainer Notes

1. The 1G Trainer steering utilizes continuously operating steering motor. Hand controller movement energizes the appropriate (one of two) counter rotating magnetic particle clutches, thereby engaging the load and effecting steering. A magnetic brake is actuated when the clutches are not engaged.
2. The 1G Trainer has simulated steering decoupling mechanisms to duplicate the LRV-to-Crew interface. Operation of this simulated mechanism, however, will not effect actual decoupling. Procedures for 1G Trainer steering decoupling are shown in Section 8.0.

1.3.5 Hand Controller

The hand controller (figure 1-11) provides the steering, speed, and braking commands to the drive controller electronics. The drive controller electronics then processes these hand controller commands to the appropriate drive motors and steering motors to effect the desired control function. The hand controller is also used as the mechanical brake lever.

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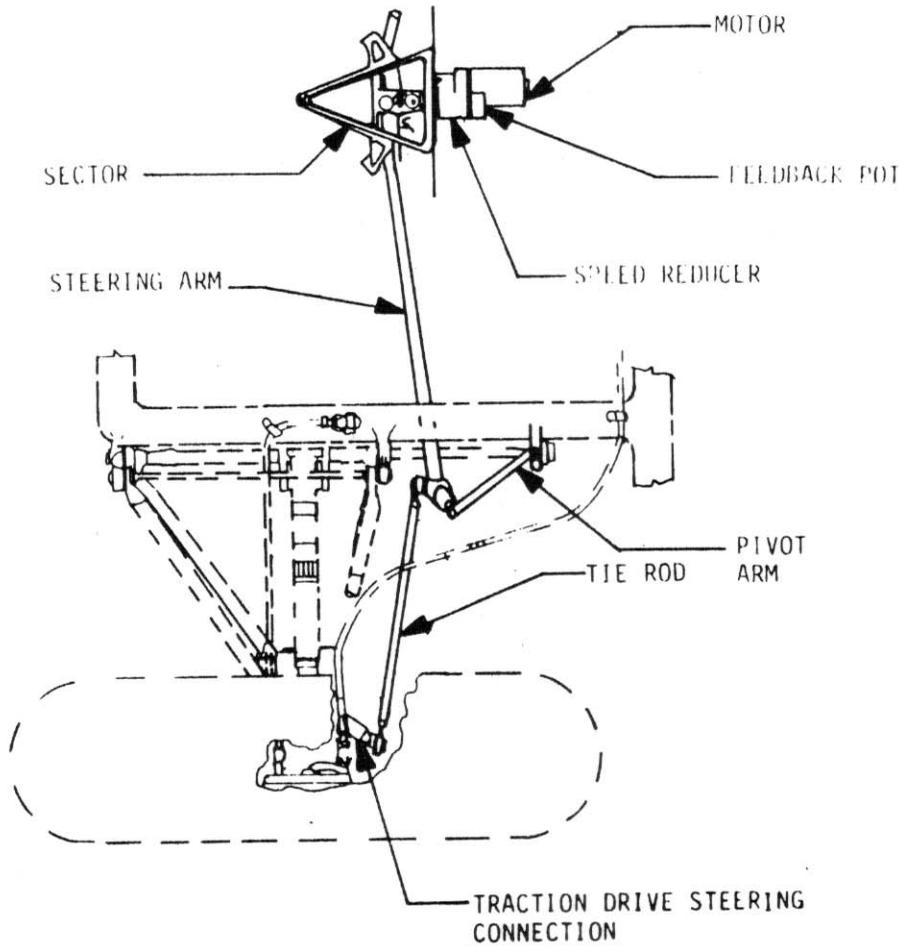


FIGURE 1-8. STEERING ASSEMBLY

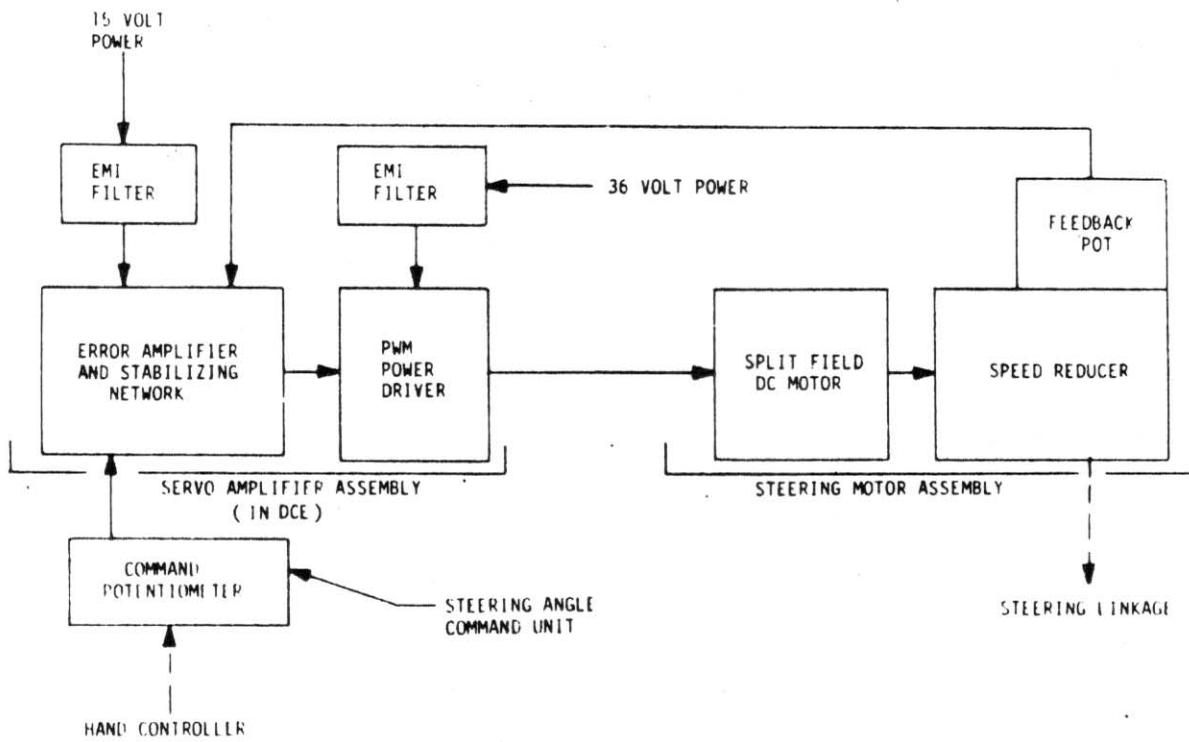
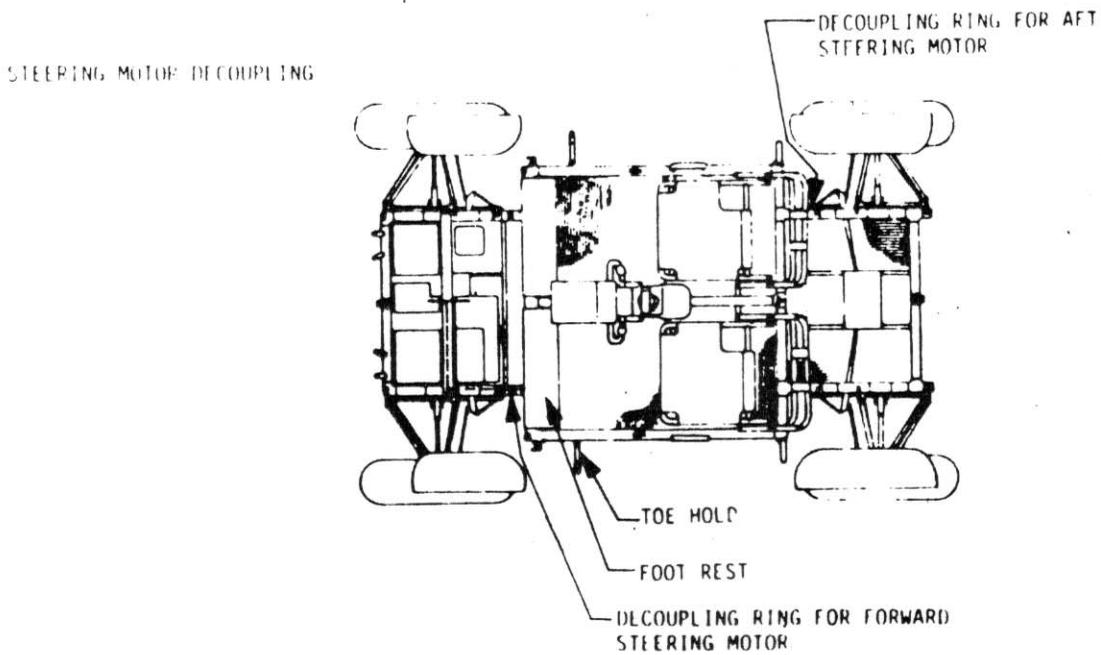
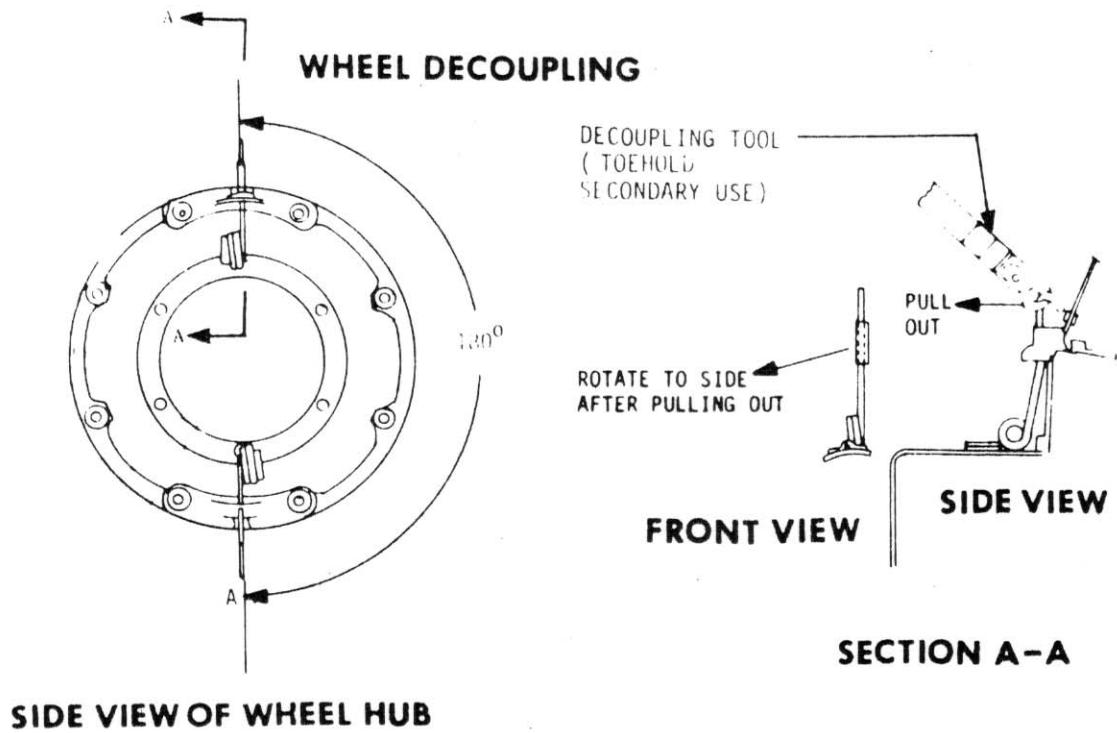


FIGURE 1-9. STEERING CONTROL BLOCK DIAGRAM



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HAND CONTROLLER OPERATION:

- T-HANDLE PIVOT FORWARD - INCREASED DEFLECTION FROM NEUTRAL INCREASES FORWARD SPEED.
- T-HANDLE PIVOT REARWARD - INCREASED DEFLECTION FROM NEUTRAL INCREASES REVERSE SPEED.
- T-HANDLE PIVOT LEFT - INCREASED DEFLECTION FROM NEUTRAL INCREASES LEFT STEERING ANGLE.
- T-HANDLE PIVOT RIGHT - INCREASED DEFLECTION FROM NEUTRAL INCREASES RIGHT STEERING ANGLE.
- T-HANDLE DISPLACED REARWARD - REARWARD MOVEMENT INCREASES BRAKING FORCE. FULL 3 INCH REARWARD APPLIES PARKING BRAKE. MOVING INTO BRAKE POSITION DISABLES THROTTLE CONTROL AT 15° MOVEMENT REARWARD.

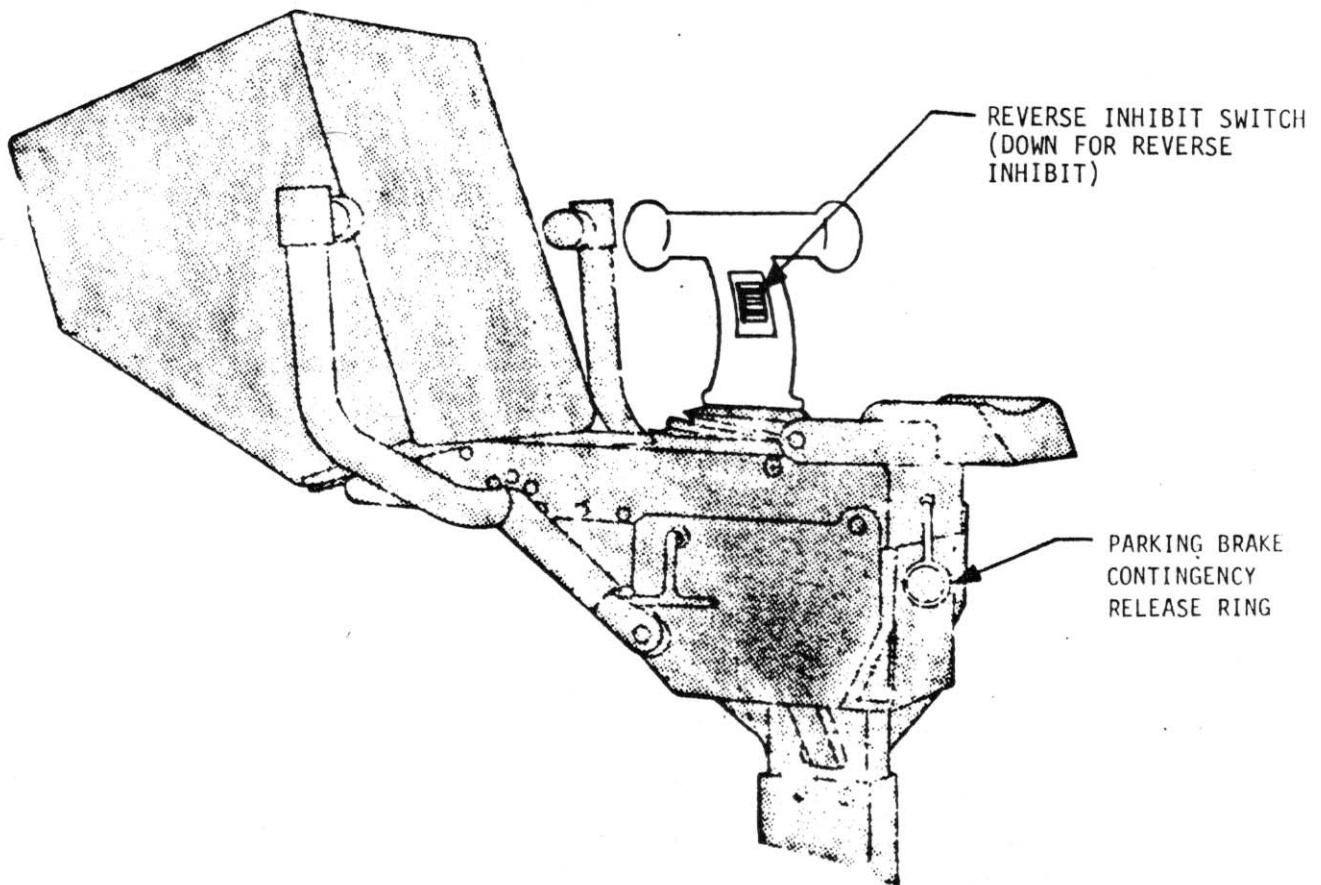


FIGURE 1-11. HAND CONTROLLER

1.3.5.1 Speed Control

Forward movement of the hand controller about the T-handle throttle pivot axis proportionately increases forward speed. A neutral dead band exists for about the first 1.5 degrees of forward motion. A constant torque of about 6 inch-pounds is required to move the hand controller beyond the limit of the dead band (figure 1-12). The nine degree position corresponds to a pulse duty cycle of approximately 50 percent, at each drive motor, i.e., the motors are at 50 percent of maximum speed condition. The maximum power setting is achieved by pivoting the hand controller to the hard stop (maximum) position at approximately 14 degrees. To decelerate, the hand controller is pivoted rearward. The torques required are shown in figure 1-12. To place the vehicle in neutral, the hand controller is pivoted rearward to the zero ($\pm 1/2$) degree position.

With the reverse inhibit switch in the down position, the hand controller can be pivoted forward only, thereby preventing inadvertently placing the vehicle in reverse.

To operate the vehicle in reverse, the reverse inhibit switch is placed in the up position and the hand controller pivoted rearward about the throttle pivot point. Torque vs. displacement characteristics for reverse are identical to forward speed operation as shown by figure 1-12.

The vehicle must be brought to a full stop before a direction change is commanded. Direction change is automatically inhibited at vehicle speeds greater than 1 KPH.

The hand controller will remain in the selected forward or reverse speed position in the crewmen "hands off" condition.

1.3.5.2 Steering Control

Pivoting the hand controller left or right about the roll pivot point proportionally changes the wheel steering angle. The steering control, like the throttle control, has a 1/2 degree neutral dead band on either side of zero. (See figure 1-13). A torque of 7 in-lbs. is required to roll the hand controller beyond the neutral position to begin steering angle change. Torque required for increasing the displacement angle about the roll pivot point increases linearly until a displacement of approximately 9 degrees is reached. At the 9 degree position, a soft stop is encountered which requires a step-function torque increase of 5 in-lbs. to pivot the hand controller further outboard for increasing the steering angle. After passing the soft stop